

## Introduction

The Ninth International Mars Society Convention, sponsored by NASA, was held in Washington DC August 3-6, 2006.

Over 400 people attended. Speakers included

NASA Administrator Mike Griffin, NASA Associate Administrator for Exploration Scott Horowitz, NASA Associate Administrator for Legislative Affairs Brian Chase, in addition to the presentation by CVMR® , which follows:

# CVMR

Chemical Vapour Metal Refining Inc.

Toronto, Ontario, Canada

Presentation to the Ninth International Mars Society Convention

Washington, DC

August 4, 2006

# Presentation Agenda

- Introduction to CVMR and Chemical Vapour Refining Process.
- Production of net shapes directly from ore.
- Description of self-contained unit.
- Description of demonstration run using iron titanium oxide as feed material.
- Selective applications. Production of plates, tubes etc.
- Application to other metals.
- Conclusions.

# Company & Process History

- Chemical Vapour Metal Refining Inc. (CVMR)
- Toronto Plant established in 1986
- Delivery of Unique Products
- Metallurgical Production Systems
- R&D for CVD

CVMR Mission is to be

“the world leader in vapour metallurgy for extraction, refining and deposition of metals and to generate above industry average returns on investments.”

# Company & Process History

- CVMR® (Chemical Vapour Metal Refining Inc.) is a privately-held, multinational corporation - Head Office in Toronto, Canada.
- Subsidiaries in the United States, Germany, Philippines, China, Singapore and Malaysia.
- Specializes in developing technologies for extraction, separation, refining and forming of metals, based on proprietary vapour metallurgy processes.
- 22 seminal patents and 40 related patents to date.

# CVMR Business

- Designing, engineering and building of metal refineries
- Licensing its technologies
- Mining
- Developing new sources of metal supplies
- Metal refining
- Research & Development
- Manufacturing metal powders, foams and net shapes

# Achievements

- Numerous patents: process & refining base metals & PGMs
- Equipment: enhancing existing refining process
- Refineries of various sizes: modular & traditional
- Nickel ore properties: Philippines, Indonesia, Malaysia and New Caledonia (under negotiation).
- Production facilities: Refining plant in China, Deposition plant in Germany, R&D center in Canada: 4 pilot plants including full scale 1 t/day pilot plant (2 base metals, 2 PGMs), lab testing facilities, 5 CVD plants.

# Introduction to CVMR Process

- Basic process developed at the beginning of the 20th century.
- Now more than 20% of world annual nickel output is produced by means of carbonyl technology.
- Carbonyl technology is based on the ability of nickel, iron, cobalt, etc. to form volatile metal carbonyl compounds.
- CVMR has developed state-of-the-art technologies based on this 100-year old chemistry.

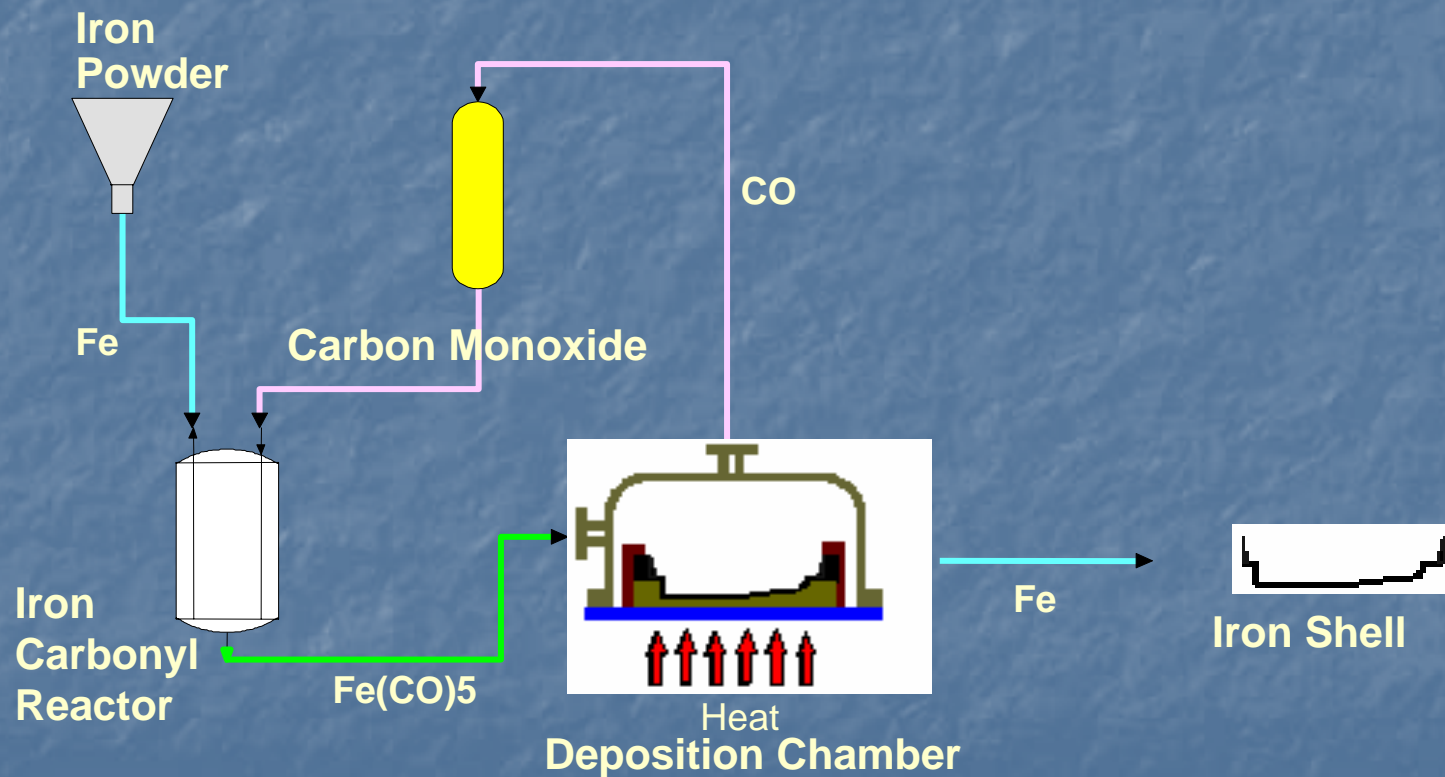


# Introduction to Chemical Vapour Metal Refining Process.

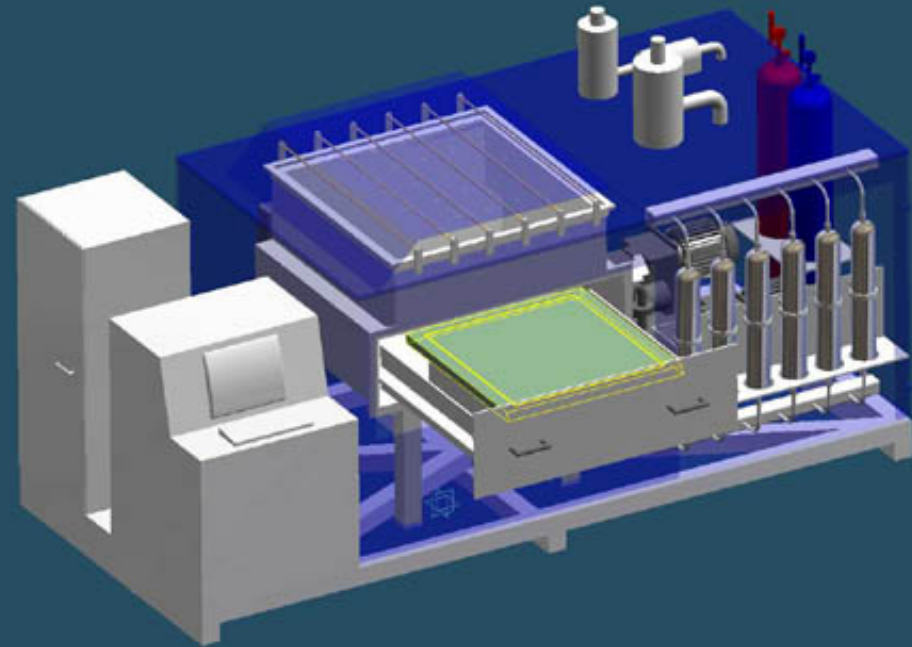
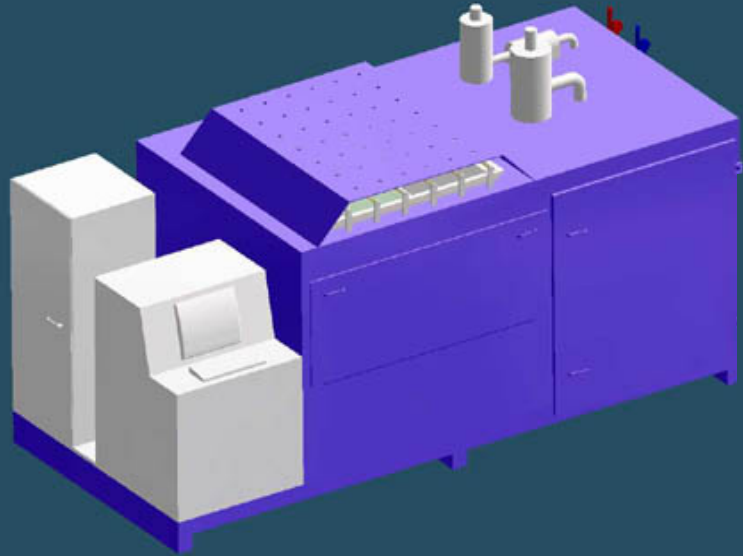
- For Refining and Deposition
  - 2 Ingredients: impure metal + Process gas = Metal volatile compound
  - Decompose to pure Metal products + Process gas (recycled)
  - Products: Metal shapes, powders, foams or metal compounds / alloys

# Chemical Vapour Deposition Process e.g. Iron

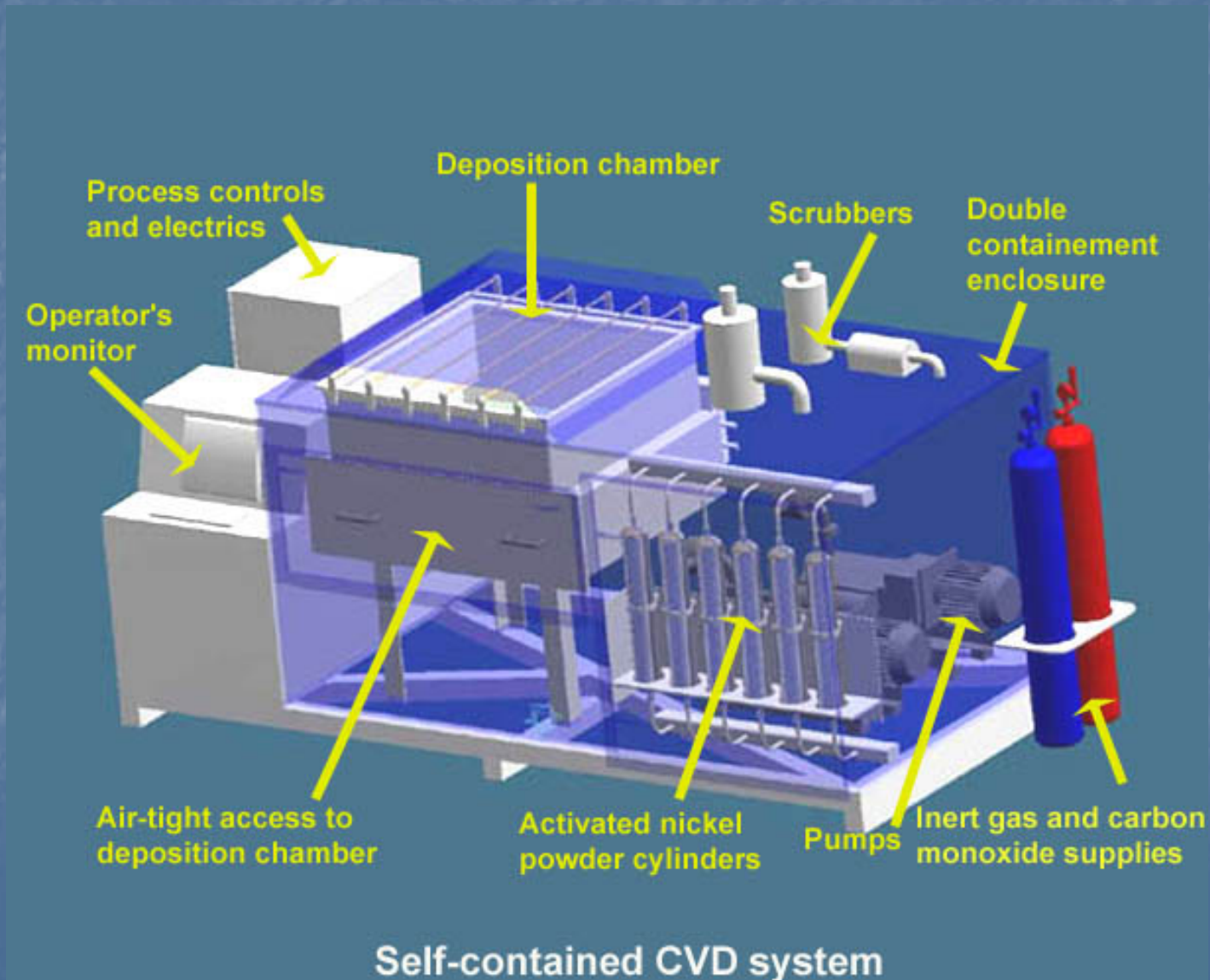
(Iron CVMR Process)



# Self-Contained CVD System Design



# Self-Contained CVD System Design



# System automation.

- CVMR's metal refining and production plants provided with DCS and requiring no manual interface with plants' operations.
- A self-contained unit is fully automated.
- All stages of the operation: including feed preparation, metal extraction and deposition cycles are pre-programmed and run automatically.
- The only time a unit needs attention is during the product removal and feed material input.
- Feed material loading can be a continuous process similar to metal refining plants.
- The final product output can be designed on a batch or continuous basis.

# Example of a Typical run

Iron extraction from Iron Titanium Oxide and production of the iron and titanium net shapes.

- Iron Titanium oxide is reduced with hydrogen to produce Iron metal and Titanium Oxide mixture:
  - $\text{FeTiO}_3 + \text{H}_2 = \text{Fe} + \text{TiO}_2 + \text{H}_2\text{O}$
- Iron is extracted from mixture by reacting with carbon monoxide to produce Iron Carbonyl:
  - $\text{Fe} + 5\text{CO (gas)} = \text{Fe(CO)}_5 \text{ (gas)}$

# A Typical run (cont.).

- Iron Carbonyl is decomposed by heat into Iron net shape and CO. Carbon monoxide is recycled.
  - $\text{Fe}(\text{CO})_5 = \text{Fe} + 5\text{CO}$
- Remaining titanium oxide is reduced by Aluminum and converted to Titanium Iodide.
  - $3\text{TiO}_2 + 4\text{Al} = 3\text{TiI}_4 + 2\text{Al}_2\text{O}_3$
- Titanium Iodide is decomposed by heat into Titanium net shape and Iodine. Iodine is recycled.
  - $\text{TiI}_4 = \text{Ti} + 2\text{I}_2$

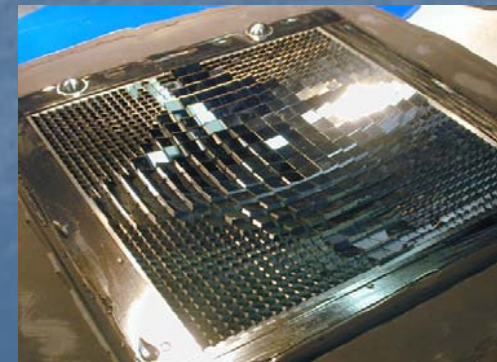
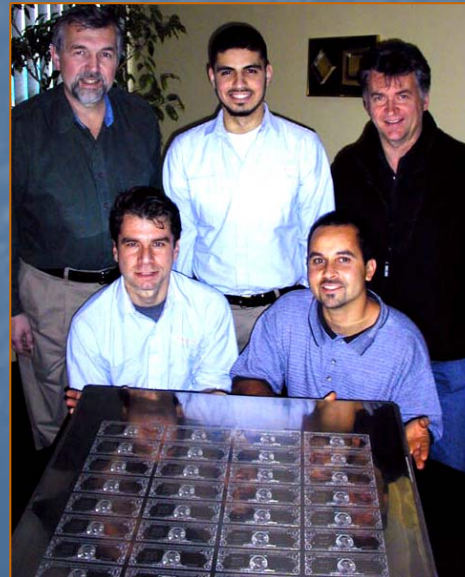
# Selected net shapes.

Examples of net shapes/moulds made by the CVD process





# Selected net shapes (cont.).



# Application to other metals.

- Iron, Nickel, Cobalt, Molybdenum and Tungsten are being refined using carbonyl process.
- Titanium and Zirconium refined using iodine process.
- Platinum, Palladium, Rhodium, Iridium, Rhenium are refined using the same process but different chemistry.

# Conclusions.

- Net shapes such as metal tubes, metal plates and metal structures can be produced directly from extraterrestrial feed material using Metal Vapour Refining Process, by remote control, to construct facilities in situ.
- Process gases will be recycled or produced from extraterrestrial sources.
- Oxygen and Water will be the by-products of the CVMR Process.
- The process can be used to utilize available resources on the Moon, Mars, NEA.
- It is possible to extract high value metals such as PGM's for use in situ or shipment to Earth.